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Abstract

This study investigates the coefficient of variation (CV) of height of males and females as a measure of inequality. We have collected a data set on corresponding male and female height CVs from 124 populations, spanning the period between the 1840s and 1980s. The results suggest that the R^2 between the two CVs is 0.39, with the male CV being greater, indicating higher plasticity.

Keywords: anthropometrics, height inequality, height, stature, inequality, measurement

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1.Introduction

In recent years, an increasing body of anthropometric literature has emerged using the coefficient of variation (henceforth 'CV') as an indicator of socioeconomic inequality in cases where conventional inequality measures are unavailable (Blum and Baten, 2011; Osmani and Sen, 2003). In this study, the author aims investigates the relationship between male and female height CVs and tests for systematic influences on this relationship.

To accomplish this task, corresponding male and female height CVs from 124 populations, spanning the period between the 1840s and the 1980s, are analysed. A set of regression models is used to test for world region-specific influences, the impact of changes in nutritional standards, and the relative status of males and females on this relationship. The empirical evidence indicates that the relationship between male and female height inequality is statistically significant with a R^2 of 0.39.

2. Methodology and advantages of height inequality measures

Distribution of height is used as an approximate determinant of inequality in the case where monetary measurements do not exist; it is also used to obtain an alternative, biological view of income inequality. Anthropometricians use stature as an alternative measure of inequality, as this measure complements conventional inequality indicators nicely and, in some respects, constitutes perhaps an even better indicator (Bassino, 2006; Blum and Baten, 2011; Komlos, 2007; Komlos and Meermann, 2007; Steckel, 1995).[2]

Final (adult) average height and height inequality reflect a birth cohort's net nutritional intake during childhood and youth; hence, it is a primary indicator of the nutritional and health statuses of a population. Average values give a clear illustration of well-being, while

[2] In a recent study, Etile (2013) uses an alternative anthropometric concept to assess socioeconomic inequality: BMI inequality is used as a target variable to evaluate the effectiveness of education policies in reducing overall health inequalities in France between 1981 and 2003.

inequality measures highlight differences in living standards. Anthropometric indicators reflect not only monetary income, but also unofficial income, e.g. from subsistence farming and black markets. Conventional income data from earlier time periods and from developing countries are often weak in quality and low in availability—two reasons for the popularity of anthropometric data among economic historians and development economists (Blum and Baten, 2011; Komlos, 1985; Komlos and Baten, 2004; Steckel, 1995).

How does socioeconomic inequality affect height inequality? If the distribution of resources that shape height distributions, such as food and medical goods, becomes unequal, heights are expected to follow suit. While a correlation between income inequality and height inequality does exist, this correlation is not perfect, since some important inputs to *biological* living standards are not traded on markets. Public health measures, for example, are often financed by public funds or statutory insurance (Sen, 2000, 2002). Food supplements for schoolchildren may improve nutrition without burdening family budgets (Blum and Baten, 2011; Moradi and Baten, 2005). In addition, height inequality reflects transfers within households. If the sole income earner of a family transfers money to relatives, only his income is included in official statistics — any utility benefitting family members is not taken into account. [3]

Deaton (2001) and Pradhan et al. (2003) have argued convincingly that measures of health inequality are important in their own right, not only in relation to income. Height inequality captures important biological aspects of inequality and may lead to new insights while serving as a countercheck for conventional indicators.

Scholars using height inequality tend to prefer the coefficient of variation (CV) over standard deviation (SD) values, since anthropologists argue that the *biological v*ariance

[3] Genetics and biology are considered the most important influencing factors shaping final height distribution. Therefore, even small differences between height distributions may express significant inequality tendencies. In practice, since the biological variance continues to contribute a large share to the total variance, most height distributions are normally distributed or very close to normal, but with a much higher standard deviation than the rather theoretical situation of perfect income equality.

increases with average height. The CV takes this effect into account and is therefore a more consistent and robust estimate of inequality (Blum and Baten, 2011; Schmitt and Harrison, 1988). The standard deviation σ is expressed as a percentage of the mean μ.[4] For a country *i* and a birth decade *t*, the CV is defined as: $CV_{it} = \frac{\sigma_{it}}{\mu_{it}} \cdot 100$

3. A selective literature review of studies using height inequality

There are several ways to utilize height inequality in research on socioeconomic inequality. This section reviews the body of literature which uses CV as a measure of inequality in stature as a measure of socioeconomic inequality.[5] Two pioneer studies on anthropometric inequality use an almost complete compilation of height data from Bavarian conscripts during the 18th and 19th centuries (Baten, 1999, 2000). Baten demonstrates that height is distributed normally around an arithmetic mean and can therefore be used in empirical analyses, often without any transformation. Similarly, Quiroga and Coll (2000) investigate Spanish height inequality and conclude that changes in the differences of heights could indicate, among other factors, shifts in income inequality. Moradi and Baten (2005) study the relationship between conventional and anthropometric measures of inequality. They show empirically that both inequality measures are related, taking into account the fact that inequality in height is influenced by factors other than monetary income inequality. Access to public goods, existence and extent of subsistence economy, and shadow markets all contribute to the determination of the final height distribution. In a similar vein, Blum and Baten (2011) find a correlation between height inequality and the corresponding wage premia of skilled

[4] In contrast to conventional applications of the coefficient of variations, CV in the field of anthropometric history is usually multiplied by 100.

[5] See Blum and Baten (2011) who provide a manual on how to distinguish several forms of within-country inequality as well as a guide on how to take into account several forms of bias. They conclude that the estimation of height inequality is a complex process since, in reality, several of the aforementioned issues occur at the same time.

construction workers compared to their unskilled peers. This indicates that inequality in monetary wealth has an impact on anthropometric inequality. Stolz and Baten (2012) adopt this methodology and use height inequality as a basis to explain the human capital selectivity of migrants in a sample of 52 source and five destination countries. Van Zanden et al. (2013) use height inequality observations to estimate inequality on a global scale during the 19th and 20th centuries relying upon historical data on average height and the corresponding height distribution. Similarly, Guntupalli and Baten (2006) use the coefficient of variation of height to trace inequality developments in India between 1915 and 1944. Meisel and Vega (2007) investigate average height and height inequality in Colombia by using information on individual height taken from identification cards. Their findings suggest that Colombian stature increased continuously between the 1900s and 1980s and height inequality, measured by the coefficient of height variation, declined. Moreover, these authors also find decreasing height gaps between men and women between the 1900s and 1950s, but the opposite between the 1960s and 1980s, indicating that until the 1950s female height had grown over proportionally while in the post-1950s male average height benefitted over proportionally from increases in biological living standards. Bassino (2006) finds that in Japan, inequality in income and access to health services can explain differences in stature across the 47 Japanese prefectures during 1892 to 1941. The variation in income contributed to changes in height during the 1930s. Japan experienced a regional convergence in terms of stature before 1914, and a divergence during the interwar period. For the US case, Godoy et al. (2005) use survey data from the National Health and Nutrition Examination Survey (NHANES) to trace variability in height (as well as variability in BMI and weight) of non-Hispanic Blacks and Whites during 1971–2002. Their results indicate increasing anthropometric inequality. These authors conclude that growing variability in anthropometric indices, particularly among the Blacks and the poor, signals growing inequality in quality of life in general. Komlos (2007) uses height inequality between regions in 19th century Habsburg and finds that there was a substantial average height gap between men living in the core versus periphery of the Monarchy. Moreover, heights did not converge across the different provinces in the 1850s; heights diverged in the 1860s, and began to converge subsequently. Komlos (2007) also finds that the convergence was limited to peripheral regions within the Habsburg Empire, located in modern-day Poland, Ukraine, Romania, and Slovakia. Convergence among the Austrian, Czech, Hungarian or Croatian areas was absent.

Several authors go one step further and use height inequality observations to empirical analyses by using anthropometric inequality as dependent or independent variables in regression models. Baten and Fraunholz (2004), for example, find that height inequality can be explained by macroeconomic openness. However, inward-oriented development strategies do not necessarily lead to the opposite result. In an analysis of the reverse causal case, Baltzer and Baten (2008) report that countries facing high height inequality tend to restrict openness in attempt to limit the negative impact of international competition.

Blum (2013) uses height inequality and average height observations to show empirically that economic inequality itself is a determinant of well-being. His study shows that an unequal distribution of resources results in unequal returns to income. Rich (tall) social groups tend to benefit only a little from an additional unit of resources; poor (short) social groups tend to benefit more — compared to their taller peers — since marginal returns to income are relatively high. Redistribution of resources from rich to poor strata may increase average height (well-being) because gains of the poor counterbalance or even outweigh.

The aforementioned studies all pertain to height inequality, but a straightforward and safe comparison of their results is not yet possible. Several of these studies use female height data taken from the *Demographic and Health Surveys* (DHS); unfortunately, few DHS datasets provide corresponding figures for males. It is no surprise that several studies pertaining to developments during the 20th century, particularly the second half, base their empirical analyses on female data in the absence of alternative (male) data (Baltzer and Baten, 2008; Baten and Fraunholz, 2004; Moradi and Baten, 2005; Pradhan et al., 2003).

4. Data and methodology

In this analysis, data from 124 human populations are used. Each observation consists of a pair of corresponding male and female height distributions, each measured as the coefficient of variation of height. Observations with less than 30 individuals are excluded to limit random biases. The data are derived from anthropological studies and health surveys; female CV observations were added for the purpose of this study). All observations were assigned to individuals' decade of birth since nutritional and health statuses during the early years of life are the most important determinants of final adult height. By performing this step, a reflection of living conditions leading to the final height distributions of the male and female populations can be obtained.

Birth cohorts cover various periods ranging from the 1840s to the 1980s, but the majority of observations stem from the 20th century. All observations are labeled by world region-of-origin. Europeans, including populations of predominant European descent, account for about 45 percent of observations. A smaller share of observations (27 percent) is based on Asian populations, about 18 percent stem from Latin America and the Caribbean. Six percent and five percent of all observations are derived from Sub-Saharan African and Middle Eastern and North African countries, respectively (Table 1, Figure 1).

[include Table 1 and Figure 1 here]

5. Results

The scatter plot shows the positive correlation between male and female height inequality as indicated by the dashed trend line (Figure 2). The positive correlation indicates that both male and female height inequality are determined by similar forces. However, the R^2 in this bivariate regression is only 0.39, suggesting that possibly other, unobserved factors do have an impact of the male-female CV relationship, potentially leading to relatively low explanatory power of the basic model (see Table 2 for some tests on this hypothesis).

[include Figure 2 here]

A solid line at an angle of 45° is inserted indicating perfect correlation. The fact that the slope of the regression line is slightly less than the 45° indicates that the female CV's tend to be slightly lower than the male CVs. In addition, a set of regression models is used to test for this relationship (Table 2). Models one and two are designed as an estimation of male CVs on the basis of female CVs. Model one is a bivariate regression whereas model two controls for time fixed-effects. Both models suggest that a male height CV is a function of female height CV (and vice versa); the inclusion of time fixed-effect hardly alters this relationship, but it increases the R^2 to 0.45.

[include Table 2 here]

Models three to five are used to test for the robustness of the result obtained in model one. The typical strategy to test for robustness involves adding a select number of variables to the basic model. In the case at hand, this strategy would likely lead to problems related to the econometric methodology. A central prerequisite of an unbiased regression model is independence between explanatory variables. This condition would not be fulfilled if additional explanatory variables were entered into models one and two since any correlate of male CV is most likely also a correlate of female CV given how closely related the two measures are. To solve for this, an alternative dependent variable was constructed for all robustness tests. Instead of a height CV, models three to five use the ratio of male and female CV. If there are factors influencing the empirical relationship between male and female height inequality, this variable's coefficient will be large and statistically significant.

Model three controls for world region-specific effects, accounting for differences in human physiology and dietary patterns that could have differing impacts on male and female height distributions. Several studies find that, by and large, average height, is a function of environmental conditions such as nutrition and health. The only systematic influence which appears to be independent of environmental factors is dietary patterns, especially consumption of animal-based foodstuffs due to lactose intolerance or cultural and religious taboos. Recent evidence, hovever, indicates that the magnitude of this influence is minor (Blum, 2013; Komlos and Baten, 2004; Steckel, 1995). In model three, three binary variables are included to capture world region-specific effects. Reference category is the group of predominantely European countries (Europe and Anglo-Saxon settlements). The coefficients of binary variables controlling for Asian, Latin American and Caribbean, Sub-Saharan African and predominantly Muslim countries in the Middle East and North Africa do not suggest that regionality exerts a substantial influence on the relationship between male and female CVs.

Model four controls for the economic development stage by adding average height as an independent variable. The underlying hypothesis is motivated by an anthropometric study investigating the (average) height dimorphism between male and female groups. Gustafsson and Lindenfors (2004) argue that often a sexual (average) size dimorphism (SSD) among mammals is observed; in this group, males are often the larger sex. These authors state that in mammalian species, SSD tends to increase with body size. If this is also the case among human populations, then the question arises as to whether this phenomenon changes the relationship between male and female height *inequality*. Model four tests for this relationship.

Average male height in centimeters, obtained from the same sources that provided the height inequality measures, is included as a measure of population “size” (in centimeters). The weak and statistically insignificant correlation between average height and the dependent variable indicates that the male-female CV ratio is not a function of average height or the stage of economic development.

Model five is motivated by several studies investigating the role of women in society and economy. A large body of evidence suggests that the relative position of women in a society depends on factors relating to relative female labor participation, relative female educational opportunities, relative property rights and other legal barriers (Duflo 2012). For example, gains in female education in absolute and relative terms compared with male education may increase incentives for women to work outside their households and/or outside agriculture. When women participate in labor markets, they are likely to receive lower wages for performing the same work compared with their male peers (Mammen and Paxson 2000).

The rationale behind testing for a statistical impact of these factors is that differences in education, labor participation, and wages between men and women not only reflect differences in societal and economic status, but may also reflect differences in household spending patterns. There is considerable evidence that: a) households do not necessarily pool their incomes, suggesting that economically weaker family members are dependent on the main income earners, and b) families in which women control more resources, invest more in their children (Dwyer and Bruce, 1988; Hoddinott and Haddad, 1995; Mammen and Paxson, 2000; Schultz, 1999; Thomas, 1997; Udry, 1996). It is reasonable to test whether the relative economic status of women affects the relationship between male and female height inequaliy as it is possible that any of the aforementioned factors may influence one part of the height distribution more than other parts.

Mammen and Paxson (2000) suggest using relative mortality as a proxy for relative female (health) status in a society since mortality patterns are very similar to those for women's level of education. However, in the absence of empirical data on labor participation, education and health proxies covering the period under observation in this study, the author uses relative biological living standards as an outcome of the aforementioned processes, measured as average male height divided by average female height. In model five the result of this test is provided. The corresponding coefficient indicates that increasing male to female height-ratio by one unit increases relative height inequality by 1.51 units. This effect, however, is neither statistically significant nor as large as it seems at first sight: the range of the relative height variable is 0.066 in total, indicating that increasing the minimum value to the maximum value in the relative height distribution increased the dependent variable by approximately 0.1 units – a value of similar magnitude as the world region variables (Table 3).[6]

6. Conclusion

A data set on corresponding male and female height inequality observations from 124 populations, spanning the period between the 1840s and the 1980s, is used to test for systematic differences in the relationship between male and female height inequality in a set of regressions models. Height inequality is measured as the coefficient of variation of height (CV).

The results suggest that there is a positive relationship with an R^2 of 0.39 between the two CVs, with male CV being greater, indicating higher plasticity. Factors related to world region characteristics, overall nutritional status, and relative nutritional status of females, are

[6] Two models are not shown in Table 2: one model tests for a U-shaped relationship between the stage of economic development by including male height and a squared term of this variable as it has been argued that development may bring initial declines in the proportion of women participating in the labor force, but increases in later stages (Goldin, 1995; Mammen and Paxson, 2000; Manzel and Baten, 2009). In another model, only controls for time fixed-effects are included to rule out time-trend biases. The results of these robustness tests fail to indicate either a U-shaped relationship nor an underlying time-trend bias in the estimation function generated in model one.

found to be relatively weak. The knowledge provided by this study will help to understand the nature of male and female height inequality, especially their relationship.

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Appendix:

Table 1: Data coverage by world region

Origin	***N***
Europe and Western Offshoots	56
Asia	34
Latin America & Caribbean	22
Sub-saharan Africa	6
Middle East and North Africa	6
Total	**124**

Source: See table 4 for a full list of countries and data sources.

Table 2: Estimated relationship between male and female height inequality

Model	(1)	(2)	(3)	(4)	(5)
	Dependent Variable				
	Male CV		CV ratio		
Female CV	0.58***	0.55***			
	(0.00)	(0.00)			
Asia			-0.00	-0.01	-0.01
			(0.97)	(0.78)	(0.89)
Middle East & North Africa			-0.07	-0.07	-0.08
			(0.14)	(0.14)	(0.12)
Sub-Saharan Africa			0.03	0.03	0.05
			(0.42)	(0.56)	(0.32)
Latin America & the Caribbean			-0.05	-0.06	-0.06
			(0.11)	(0.14)	(0.14)
Average (male) height; in cm				-0.00	-0.00
				(0.64)	(0.54)
Relative height (male/female)					1.51
					(0.23)
Time fixed-effects	NO	YES	YES	YES	YES
Constant	1.55***	2.22***	1.10***	1.29***	-0.26
	(0.00)	(0.00)	(0.00)	(0.00)	(0.84)
N	124	124	124	124	124
R^2	0.39	0.45	0.13	0.13	0.15

Note: See descriptive statistics in table 3. Robust standard errors are estimated. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level. P-values in parentheses. Reference category is the group of European countries, including Anglo-Saxon settlements. "CV ratio" is defined as male CV divided by female CV. The corresponding formula to derive female CV on the basis of male CV is: $CV_f = 1.106 + CV_m*0.673$.

Table 3: Descriptive statistics

	N	Mean	Standard Deviation	Min	Max
Male CV	124	3.61	0.38	2.02	4.69
Female CV	124	3.53	0.41	1.99	4.55
Average male height	124	169.90	5.36	154.80	184.00
Asia	124	0.27	0.45	0.00	1.00
Latin America and Caribbean	124	0.18	0.38	0.00	1.00
Sub-Saharan Africa	124	0.05	0.22	0.00	1.00
Middle East and North Africa	124	0.05	0.22	0.00	1.00
Relative height (male/female)	124	1.08	0.01	1.05	1.11
CV ratio	124	1.03	0.10	0.78	1.54

Table 4: Countries and periods covered by the data set, including sources

Country	**Period covered**	**Sources**
Angola	1940s	Santos David 1972
Australia	1850s-1870s	Powys 1901
Australia	1960s-1970s	Austr. Bureau of Statistics 1998
Bolivia	1930s-1980s	Godoy et al. 2006
Canada	1930s-1950s	Bailey, Carter, Mirwald 1982
Chad	1950s	Crognier 1973
Chile	1940s-1950s	Valenzuela et al. 1978, 1979
China	1910s-1920s	Morgan 2004
Congo	1950s	Austin 1979
Croatia	1930s	Skaric-Juric et al. 2003
Cuba	1950s	Jordan 1979
Czech Republic	1890s-1950s	Sittenberger et al. 1941; Fetter, Hajnis 1962; Webb 2008
Estonia	1890s-1910	Aul 1997
Ethiopia	1930s	Harrison et al. 1969
Finland	1880s	Kajava 1927
Germany	1890s	Sittenberger et al. 1941
Greece	1950s-1960s	Manolis et al. 1995
Guatemala	1920s;1970s	Russell 1976; Torun et al. 2002
Haiti	1920s-1930s	Benoist 1962; Basu 1976
Hungary	1950s-1970s	Gyenis, Joubert 2004
India	1840s-1890s	Brennan et al. 1994
Ireland	1850s-1910s	Young et al. 2008
Jamaica	1890s-1930s	Davenport, Steggerda 1929; Ashcroft et al. 1966
Japan	1930s-1960s	Kimura 1984
Korea (North)	1950s-1980s	Pak et al., 2011
Korea (South)	1950s-1980s	Pak et al., 2011
Libya	1890s	Sabatini 1936
Namibia	1880s	Wells 1952
Netherlands	1960s-1970s	Niewenweg 2003
Norway	1900s-1960s	Tambs et al. 1992
Papua New Guinea	1930s	Littlewood 1972
Poland	1930s-1950s	Webb 2008
Puerto Rico	1900s-1940s	Thieme 1959; Knott 1963
Russian Federation	1930s-1950s	Webb 2008
Slovakia	1920s-1940s	Fetter, Hajnis 1962
Sri Lanka	1960s-1980s	Ranasinghe et al. 2010
Sudan	1930s	Sukkar 1976
Switzerland	1930s	Heimendinger 1958
Taiwan	1920s-1940s	Morgan, Liu 2007
Turkey	1930s; 1960s-1980s	Özer 2008
United Kingdom	1890s-1920s	Kemsley 1951

Figure 1: data coverage by birth decade

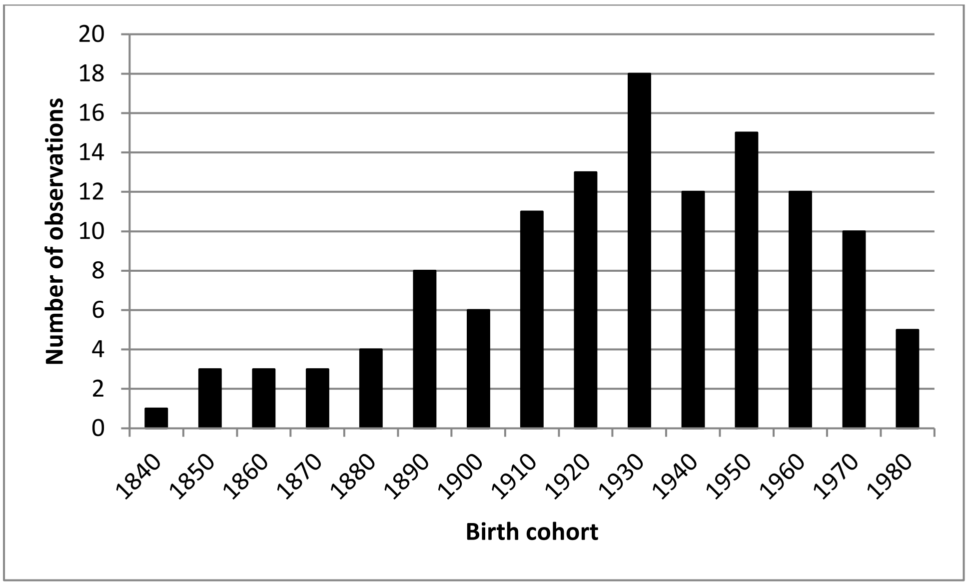

Figure 2: Relationship between male and female height CV